Implementation and development of standards for Lithium-ion energy storage technologies within the South African context

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Battery Testing road map

Battery Testing Laboratory

Activities

2013

Initiation

Commissioning 18V Battery cycle tester and HRD tester

2014

Testing Lead-acid batteries according to

SANS2:2013

IEC60095-1

Materials characterization laboratory

Implementation of ISO17025 quality system

2015

Inter-laboratory comparative testing

Accreditation obtained

Lithium-ion cell testing equipment arrives

2016

Commissioning of Lithium-ion cell and EIS tester

Delivery of Climatic chamber May 2016

Testing and Inter-laboratory comparative testing according to IEC62620

2017

Start/stop testing

Lithium-ion module testing (0-60V)

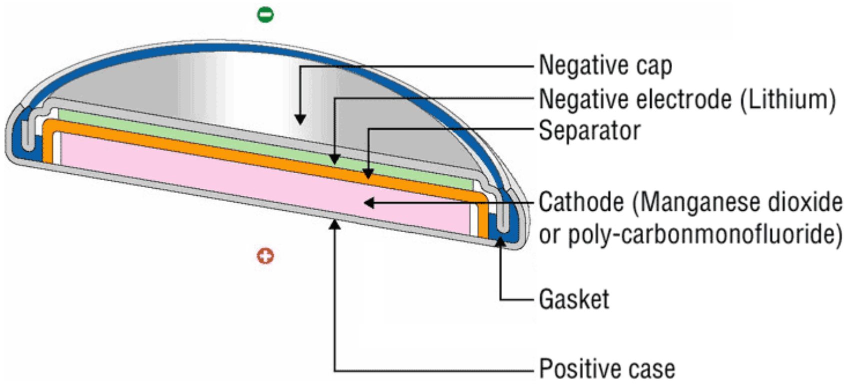
Scope of accreditation to include lithium ion testing activities

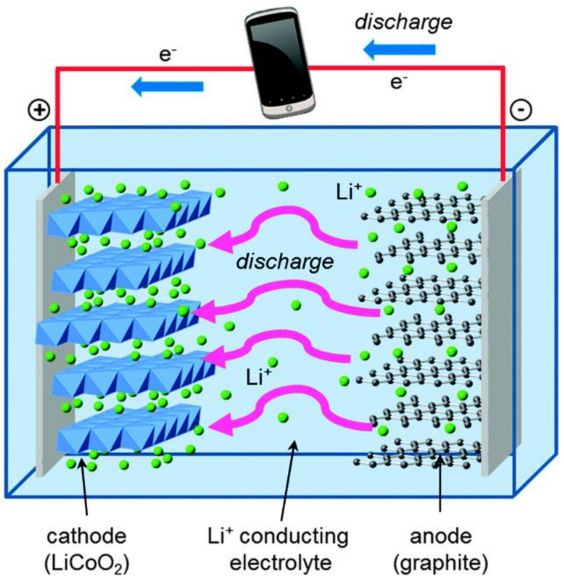
sanas Testing Laboratory

T-0676

Intercalation chemistry

- Lithium Cobalt Oxide ($LiCoO_2$)
- Lithium Manganese Oxide ($LiMn_2O_4$)
- **Lithium Nickel Manganese Cobalt Oxide** ($LiNiMnCoO_2$ or NMC)
- **Lithium Iron Phosphate ($LiFePO_4$)**
- Lithium Nickel Cobalt Aluminum Oxide ($LiNiCoAlO_2$)
- Lithium Titanate ($Li_4Ti_5O_{12}$)





Types of failure

- Internal short circuit and overheating could result from internal damage such as
  - Dendrite growth
  - Separator failure
  - Lithium plating
  - Nano-particles detaching from electrodes – others

- External Causes (mechanical, electrical, thermal abuse)
  - Mechanical Damage
  - External Short Circuit
  - Cell Overcharge
  - Cell Over-discharge
  - Low Temperature Recharging
  - High Temperature Storage
  - Improper Design
  - Manufacturing contamination
  - Sequential combinations of all of the above

Safety

- The volume and speed at which these manufacturing process operates can easily lead to an increase in errors
  - cell electrode alignment and inconsistent welds can contribute to short circuits that lead to failures with disastrous consequences.

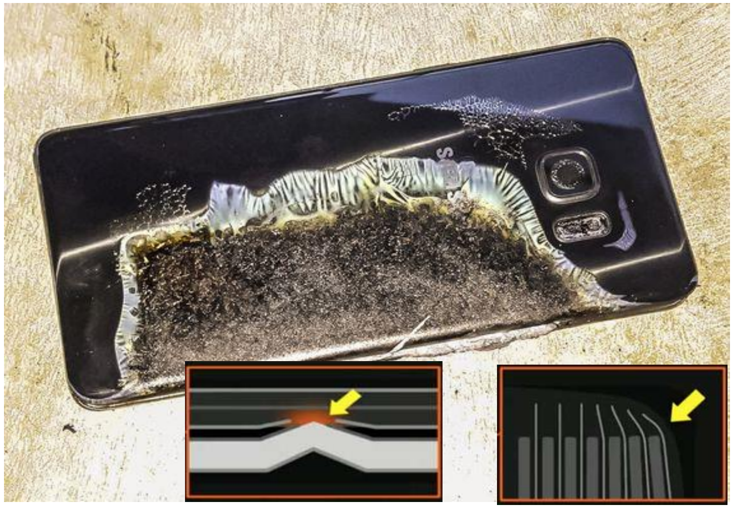


Figure 1: Galaxy Note 7 battery problems

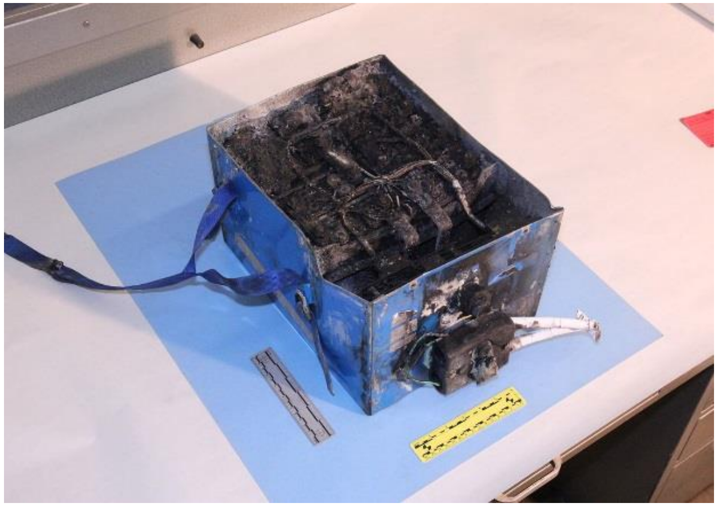


Figure 2: Boeing 787 Dreamliner battery failure

Testing Standards

- They increase safety and reduces liability
  - Traceability of testing records
- Standardisation ensures that products, services and methods are appropriate for their intended use.
  - On grid or off-grid applications
- It ensures that products and systems are compatible and interoperable.
  - Replacing international with local products
- Using standards removes barriers to trade
  - Supply local products to the international market

UN38.3

United Nations - recommendation on the transport of dangerous goods section 38.3 for lithium metal and lithium-ion batteries

Test	Test Type	Purpose
1	Altitude simulation	To simulate air transport under low-pressure conditions
2	Thermal test	Assesses cell seal integrity and electrical connections
3	Vibration	Simulates vibration during transport
4	Shock	Simulates possible impacts during transport
5	External short Circuit	Simulates an external short
6	Impact/Crush	These tests mimics mechanical above from an impact or crust that may result in an internal short circuit.
7	Overcharge	Evaluates the ability of a rechargeable battery to withstand an overcharge condition.
8	Forced discharge	Evaluates whether a cell can withstand a forced discharge condition.

SANS/IEC 62133-2 -Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications

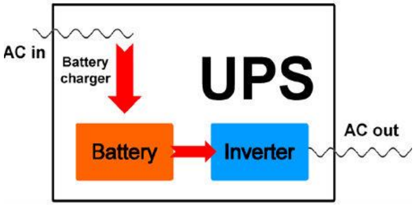
IEC 62281:2016 RLV- Safety of primary and secondary lithium cells and batteries during transport

Lithium-Ion standards for EVs

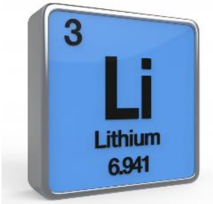
- IEC 62660-1:2010
  Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 1: Performance testing
- IEC 62660-2:2010
  Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 2: Reliability and abuse testing
- IEC 62660-3:2016
  Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 3: Safety requirements
- IEC TR 62660-4:2017
  Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 4: Candidate alternative test methods for the internal short circuit test of IEC 62660-3
- ISO/IEC PAS 16898:2012
  Electrically propelled road vehicles -- Dimensions and designation of secondary lithium-ion cells

Lithium-Ion standards for Industrial applications

- IEC 62619:2017
  Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications
- IEC 62620:2014
  Secondary cells and batteries containing alkaline or other non-acid electrolytes - Secondary lithium cells and batteries for use in industrial applications.

  - Stationary applications: telecommunications, uninterruptible power supplies (UPS), electrical energy storage system, utility switching, emergency power and similar applications.
  - Motive applications: fork-lift truck, golf cart, AGV, railway, and marine, excluding road vehicles.



Lithium-ion SLI Battery ?

- EU legislations prohibits the use of portable batteries that contain restrictive materials such as mercury, cadmium and more relevant, lead, that is not allowed to be more that 0.004% by weight (or 40ppm).

- According to number of battery consortiums regarding the future of automotive lead-acid battery the battery will still be around for a number of years - used in micro-hybrid applications and as auxiliary batteries for Lithium-ion based HEV or BEV's

Main contributors

– Cost (≈ R20 000)

- Cost (≈ R1 000)

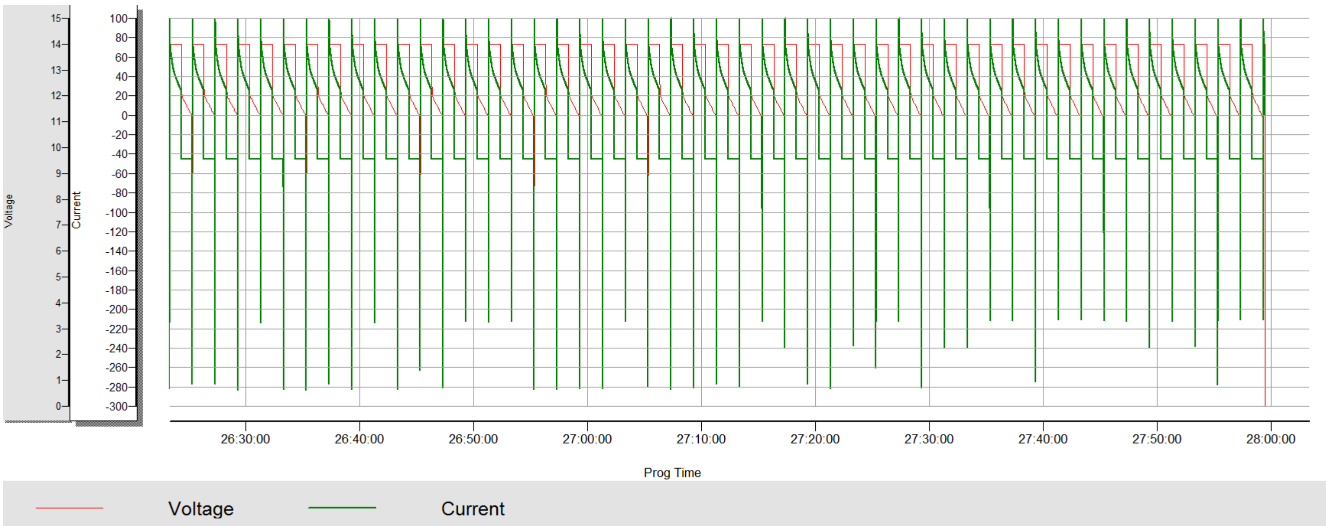
Standard development

- The replacement of the lead-acid battery with Lithium-ion batteries have already started with OEM's
- Proper standards needs to be developed in conjunction with experts and the manufacturer within the relevant legislative framework, to ensure the conformance of the product.

Test	Lead-acid	Lithium-ion
20 hour Capacity	■	■
Reserve capacity	■	■
Cranking Performance test	■	■
Charge acceptance test	■	■
Charge retention test	■	■
Corrosion test	■	
Cycle test	■	■
Water consumption test	■	
Vibration resistance test	■	■
Electrolyte retention test	■	

Start-stop (Micro-hybrid) batteries

Micro-hybrid applications requires batteries to operate in a partial state of charge and be cranked multiple times during a drive cycle, which puts additional stress on the battery



– carbon additives are added to the negative electrode to reduce the rate of sulphation of the negative plate
– the development of a hybrid type lead-acid battery, known as the Ultra-battery incorporates super-capacitor technology
– The challenge - production and raw materials for such hybrid technologies become very complicated and expensive ≈ R2 000 (2015)

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Delays in standard adoption - IEC62620:2014

- Large scale Lithium-ion batteries have already been developed as far back as 2010.

- Standard only adopted by SABS in 2017

- The timeously implementation of standard testing practices by manufacturers are very important
  - Input from industry paramount
  - Skills gap

Importance of testing

- Cell assemblers in the local marked generally rely on the relevant product specification sheets provided by manufacturers of Lithium-ion products.

- Testing of Lithium-ion cells shows that capacity values can differ by as much as 20% from that specified on the specification sheet.

- Due to lack of testing, most battery assemblers are not aware of these variables, which could lead to unnecessary performance issues and claims

Complexity of Lithium-ion battery testing

- *Test environment*

- ➢ batteries have to be tested in specialised explosion proof chambers that are controlled to simulate various temperature conditions
- ➢ modules of up to 60 V packs of up to 600V, are often done in isolated containers

Complexity of testing

External influences, such as

- External heating
- Overcharging
- Deep discharge
- Excessive charging current
- External short-circuit

Internal events, such as

- Electrode-electrolyte reactions
- Electrochemical reactions

Impacts on the lithium battery

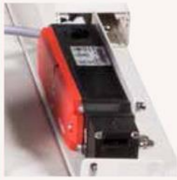
Hazard Level	Description	Classification Criteria & Effect
0	No effect	No effect. No loss of functionality.
1	Passive protection activated	No defect; no leakage; no venting, fire or flame; no rupture; no explosion; no exothermic reaction or thermal runaway. Cell reversibly damaged. Repair of protection device needed.
2	Defect / Damage	No leakage; no venting, fire or flame; no rupture; no explosion; no exothermic reaction or thermal runaway. Cell irreversibly damaged. Repair needed.
3	Leakage Δ mass < 50%	No venting, fire or flame*; no rupture; no explosion. Weight loss < 50% of electrolyte weight (electrolyte = solvent + salt).
4	Venting Δ mass ≥ 50%	No fire or flame*, no rupture; no explosion. Weight loss ≥ 50% of electrolyte weight (electrolyte = solvent + salt).
5	Fire or Flame	No rupture; no explosion (i.e., no flying parts).
6	Rupture	No explosion, but flying parts of the active mass.
7	Explosion	Explosion (i.e. disintegration of the cell)

* The presence of flame requires the presence of an ignition source in combination with fuel and oxidizer in concentrations that will support combustion. A fire or flame will not be observed if any of these elements are absent. For this reason, we recommend that a spark source be use during tests that are likely to result in venting of cell(s). We believe that "credible abuse environments" would likely include a spark source. Thus, if a spark source were added to the test configuration and the gas or liquid expelled from the cell was flammable, the test sample would quickly progress from hazard level 3 or 4 to hazard level 5.

Hazard Level 0-3

Status display

Electrical door lock



Hazard Level 4

Reversible pressure release flap

Mechanical door lock

Sealing plug with retaining clamp

Hazard Level 5-6

Permanent inertization using nitrogen or argon

Fire alarm system

Oxygen measurement

Fire detection via temperature measurement

Burst disc

Flushing device for inertization in case of fire

Hazard Level 7

Tolerable residual risk without further safety test

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Complexity of Lithium-ion battery testing

- *Operating voltages*

Chemistry	Cut-off (V)	Operating range (V)
Lithium Cobalt Oxide	2.5	3.0 - 4.2
Lithium Manganese Oxide	2.5	3.0 - 4.2
Lithium Nickel Manganese Cobalt Oxide	2.5	3.0 - 4.2
Lithium Iron Phosphate	2.0	3.0 - 3.65
Lithium Nickel Cobalt Aluminium Oxide	3.0	3.0 - 4.2
Lithium Titanate	1.8	1.8 - 2.85

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Complexity of Lithium-ion battery testing

- *Calculation of discharge currents*
  - Discharge performance at 25°

Discharge conditions		Minimum discharge capacity			
Rate of constant current	Final voltage declared by the manufacturer	Discharge rate type			
A	V	S	E	M	H
$(1/n)I_t$	Refer to 6.2	100% C_n Ah			
$0.2\ I_t$	Refer to 6.2		100% C_5 Ah	100% C_5 Ah	100% C_5 Ah
$1.0\ I_t$	Refer to 6.2		-	95% C_5 Ah	95% C_5 Ah
$5.0\ I_t$	Refer to 6.2		-	-	90% C_5 Ah

$$ItA = \frac{CnAh}{1h}$$

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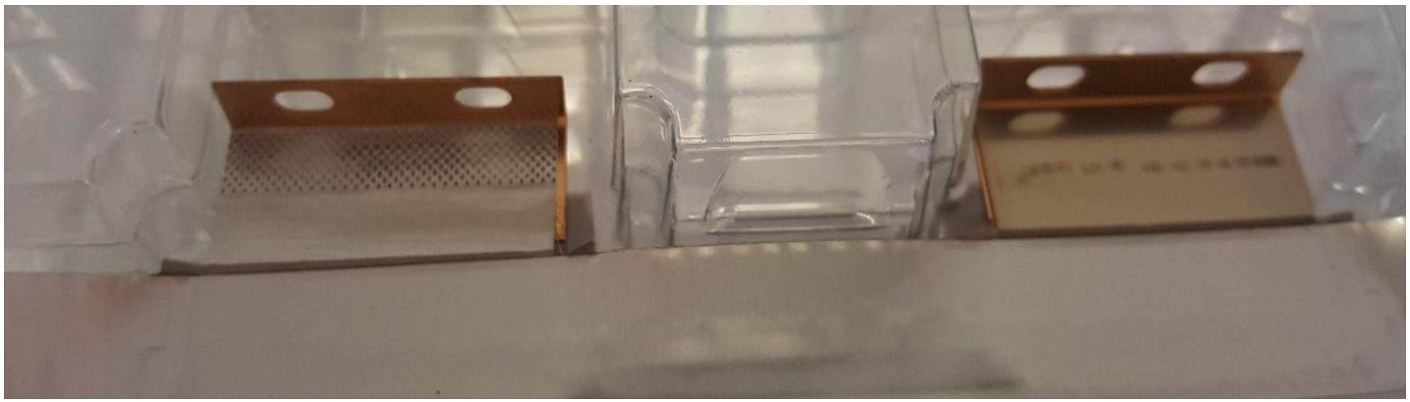
Complexity of Lithium-ion battery testing

- *Lithium-ion cells showing different connection requirements*



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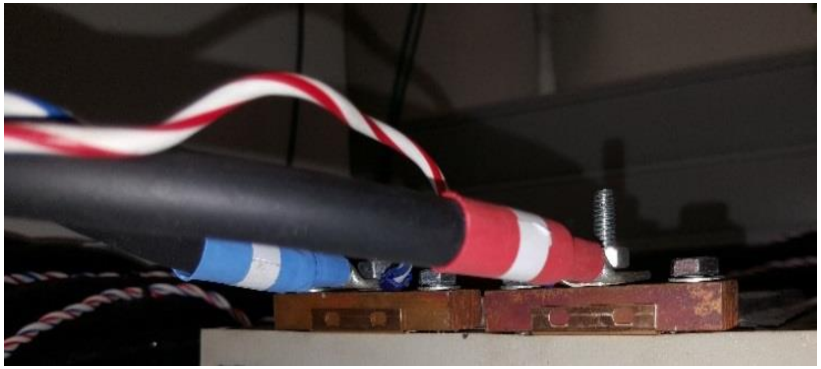
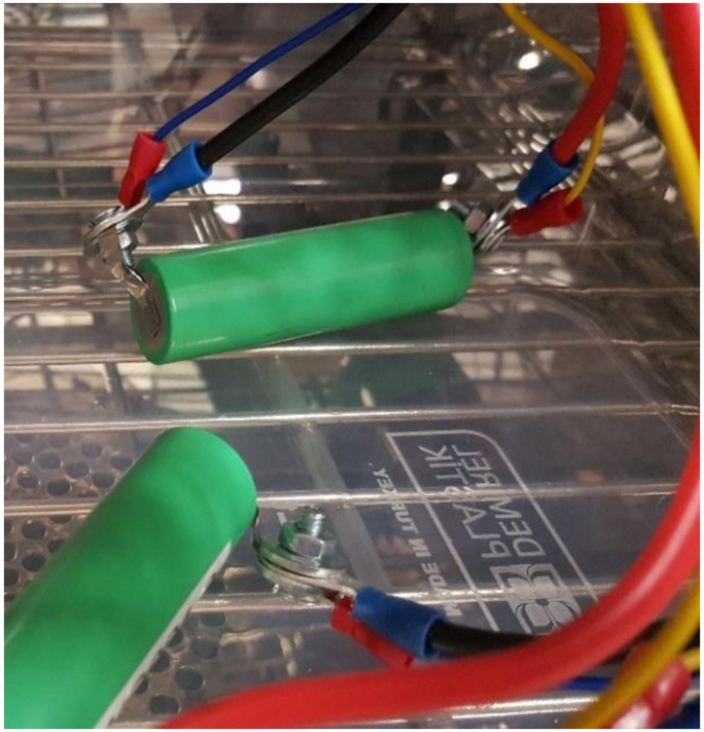
Complexity of Lithium-ion battery testing

- *Connection of cells to the cell tester*





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Complexity of Lithium-ion battery testing

- *Impedance differences obtained during AC and DC measurements (18650 –LMNC cells)*

Cell	AC impedance (mΩ)	DC impedance (mΩ)
1	14	570
2	14	665
3	13	715
4	14	645
5	14	760*

**DC impedance measured for cell 5 when using spot-welded tabs was 340 mΩ*

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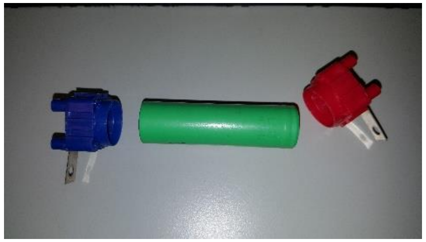
Complexity of Lithium-ion battery testing

- *Impedance differences obtained during AC measurements with and without cell holders (18650 – LMNC cells)*



Cell	AC impedance (mΩ) – With cell holder	AC impedance (mΩ) – Without cell holder
1	63	38
2	65	39
3	65	40
4	72	40
5	81	40

Complexity of Lithium-ion battery testing

Other types of issues

- Batteries - Instrument parameters and BMS conflict
  - Set parameters of instrument to allow BMS to perform its function
- *Safety*
  - *Insulated tools*
  - *Working in confined space*

Conclusion

- More focus should be given to the regulation of these Lithium-ion secondary storage devices to provide improved consumer safety

- Need active participation for the acceptance and development of standards

- Energy storage systems being implemented in residential properties for use as back up or off grid energy storage solutions – not validated and could lead to legal issues

- Battery manufacturer should make sure that he has covered all the relevant basis regarding the validation testing of his product to the relevant standards available to avoid legal prosecution

Thank You

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